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PATENT APPLICATION

of

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for

FUEL CELLS FOR USE IN PORTABLE DEVICES

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FUEL CELLS FOR USE IN PORTABLE DEVICES

Field of the Invention

The present invention relates generally to fuel cells for use in a portable electronic device and, more particularly, to the method for fabricating such fuel cells.

Background of the Invention

A fuel cell works like a battery but does not run down or need recharging so long as the fuel is continually fed to the cell. In a direct methanol fuel cell (DMFC), methanol is used as a fuel, which is put in on one side of the fuel cell while air circulates on the other side. The two sides are separated by a membrane electrode assembly (MEA), which has a proton exchange membrane (PEM) sandwiched between two electrodes. As shown in Figure 1, a fuel cell **10** includes an anode side **12** where a mixture of methanol (MeOH) and water (H_2O) (also referred to as liquid methanol) is circulated around the anode (-). On the cathode side **14**, air is circulated around the cathode (+). Through catalytic activation at the MEA, hydrogen atoms from the liquid methanol separate into protons (H+) and electrons (not shown). The electrons become the source of electricity provided by the fuel cell. Some of the protons migrate through the membrane assembly to the cathode side **14**, where they combine with oxygen and become water. While the byproduct of the spent fuel, CO_2, on the anode side is easily vented out of the fuel cell, the byproduct, water, on the cathode side must be properly taken away.

A major advantage of fuel cells over rechargeable batteries is that fuel cells can generally operate for longer periods of time without recharging. Furthermore, "recharging" a fuel cell can be accomplished almost instantaneously by refueling with liquid methanol. In contrast, recharging a battery takes hours to complete.

Currently, a DMFC is made of a single MEA, wherein a single PEM is used. The MEA and the PEM are usually designed to suit the dimensions of the portable device. If the PEM in a fuel cell is defective, rendering the fuel cell non-functioning, the MEA or the entire PEM must be replaced. It is thus advantageous and desirable to provide a fuel cell wherein the MEA can be repaired without discarding the entire PEM in order to reduce the associated cost.

Summary of the Invention

It is a primary objective of the present invention to reduce the cost in fabricating and repairing a fuel cell for use in a portable device, such as a laptop PC, notebook PC or tablet PC. This objective can be achieved by disposing a plurality of PEM segments such that only the defective segments will be replaced in a non-functioning direct methanol fuel cell.

Thus, according to the first aspect of the present invention, there is provided a method of fabricating a fuel activation assembly for use in a fuel cell, the fuel cell comprising a first cell compartment for containing a first fuel component and a second cell compartment for containing a second fuel component, wherein the fuel activation assembly is disposed between the first cell compartment and the second cell compartment so as to activate the first fuel component for producing protons in the first cell compartment and for channeling the protons to the second cell compartment. The method comprises the steps of:

providing a substrate having a plurality of apertures; and

securely attaching a plurality of membrane electrode assembly segments to the substrate over the apertures, wherein each membrane electrode assembly segment has a first side and an opposing second side, the second side adjacent to the second cell compartment, the first side adjacent to the first cell compartment for activating the first fuel component in order to produce the protons and for channeling at least part of the protons from the first cell compartment to the second cell compartment via the apertures through the membrane electrode assembly segments.

The attachment of the membrane electrode assembly segments to the substrate can be

achieved by a heat bonding process or by applying an adhesive layer, creating a barrier separating the first side from the second side of each membrane electrode segment, thereby preventing the first fuel component from entering the second cell compartment and the second fuel component from entering the first cell compartment. The adhesive is resistant to the fuel components.

According to the second aspect of the present invention, there is provided a fuel cell, which comprises:

a first cell compartment for containing a first fuel component;

a second cell compartment for containing a second fuel component; and

a fuel activation assembly disposed between the first cell compartment and the second cell compartment, the fuel activation assembly comprising:

a substrate having a plurality of apertures; and

a plurality of membrane electrode assembly segments securely attached to the substrate over the apertures, wherein each membrane electrode assembly segment has a first side and an opposing second side, the second side adjacent the second cell compartment, the first side adjacent the first cell compartment for activating the first fuel component to produce protons in an activation process and for channeling at least part of the protons from the first cell compartment to the second cell compartment via the apertures through the membrane electrode assembly segments.

The activation process produces an electrical current, and the fuel cell further comprises:

a first electrically conducting terminal operatively connected to the first cell compartment; and

a second electrically conducting terminal operatively connected to the second cell compartment, so as to allow a current load to connect to the first and second electrically conducting terminals to use the electrical current.

The first fuel component comprises substantially a mixture of water and alcohol, and the substrate is resistant to water and alcohol. The alcohol comprises substantially methanol. The second fuel component comprises substantially air.

Each membrane electrode assembly segment comprises a proton exchange membrane disposed between two electrode layers.

Each membrane electrode assembly segment further comprises two diffusion layers, each covering one of the electrode layers.

According to the third aspect of the present invention, there is provided a membrane electrode assembly for use in a fuel cell. The fuel cell comprises:

a first cell compartment containing a first fuel component; and

a second cell compartment containing a second fuel component, said membrane electrode assembly comprising:

a substrate having a plurality of apertures; and

a plurality of fuel activation segments securely attached to the substrate over the apertures, wherein each fuel activation segment has a first side and an opposing second

side, the second side adjacent the second cell compartment, the first side adjacent the first cell compartment, for activating the first fuel component in order to produce protons in an activation process, and for channeling at least part of the protons from the first cell compartment to the second cell compartment via the apertures through the membrane electrode assembly segments.

Advantageously, each fuel activation segment comprises:

a first electrode layer on the first side;

a second electrode layer on the second side; and

a proton exchange membrane disposed between the first and second electrode layers.

The first electrode layer and the second electrode layer of each fuel activation segment are operatively connected to the first electrode layer and the second electrode layer, respectively, of other fuel active segments such that the fuel activation segments are electrically connected in parallel.

Advantageously, at least some of the fuel activation segments are electrically connected in series, such that the first electrode layer and the second electrode layer of each of said at least some of the fuel activation segments are operatively connected to different ones of the first and second electrode layers of different fuel activation segments. Alternatively, the fuel activation segments are electrically connected in a combination of a series connection and a parallel connection.

According to the fourth aspect of the present invention, there is provided a portable electronic device comprising:

an electronic unit for processing signals or data; and

a fuel cell for providing electricity to the electronic unit, the fuel cell comprising:

a first cell compartment containing a first fuel component;

a second cell compartment containing a second fuel component; and

a fuel activation assembly disposed between the first cell compartment and the second cell compartment, the fuel activation assembly comprising:

a substrate having a plurality of apertures; and

a plurality of membrane electrode assembly segments securely attached to the substrate over the apertures, wherein each membrane electrode assembly segment has a first side and an opposing second side, the second side adjacent the second cell compartment, the first side

adjacent the first cell compartment, for activating the first fuel component in order to produce protons in an activation process and for channeling at least part of the protons from the first cell compartment to the second cell compartment via the apertures through the membrane electrode assembly segments.

The portable electronic device can be a notebook computer, a laptop computer, a tablet computer, a personal digital assistant device, or the like.

The present invention will become apparent upon reading the description taken in conjunction with Figures 2 - 8.

Brief Description of the Drawings

Figure 1 is a schematic representation showing a prior art direct methanol fuel cell.

Figure 2a is a schematic representation illustrating an embodiment of the fuel cell stack in a fuel cell, according to the present invention.

Figure 2b is an exploded view of the fuel cell stack of Figure 2a.

Figure 3 is a schematic representation illustrating an MEA segment of the present invention.

Figure 4a is a schematic representation illustrating the attachment of an MEA segment to the substrate, according to the present invention.

Figure 4b is a schematic representation illustrating a different way to attach an MEA segment to the substrate.

Figure 4c is a schematic representation illustrating yet another way to attach a MEA segment to the substrate.

Figure 5 is a schematic representation illustrating a method for collecting electrical current from the MEA segments.

Figure 6a is a schematic representation illustrating a different method for collecting electrical current from the MEA segments.

Figure 6b is a schematic representation illustrating yet another way to collect electrical current from the MEA segments.

Figure 7a is a schematic representation illustrating a two-cell MEA segment.

Figure 7b is a schematic representation illustrating a four-cell MEA segment.

Figure 7c is a schematic representation illustrating a six-cell MEA segment.

Figure 8 is a schematic representation illustrating another embodiment of the fuel cell stack in a fuel cell, in which the sizes of MEA segments are different.

Best Mode for Carrying Out the Invention

The fuel cell, according to the present invention, comprises a plurality of MEA (membrane electrode assembly) segments, each of which has a separate PEM (photon exchange membrane) and two electrode/diffusion layers for catalytic activation. As shown in Figures 2a and 2b, a fuel cell stack **100** comprises a substrate **140** having a plurality of openings **142**, and a plurality of MEA segments **110** securely attached to the substrate **140**, with each MEA segment **110** at an opening **142**. The substrate **140** is made of a material that is stiff enough to serve as a mechanical frame for supporting the MEA segments. At the same time, the material is also resistant to methanol. For example, the substrate **140** can be made of Teflon, or FR4 (a laminate made of woven fiberglass fabric saturated with an epoxy resin).

The MEA segment **110**, as shown in Figure 3, substantially comprises a proton exchange membrane (PEM) **120** disposed between two activation layers **112** and **114**. It is understood that the activation layer **112** comprises a diffusion layer and an electrode disposed between the diffusion layer and the PEM **120**. Likewise, the activation layer **114** comprises a diffusion layer and an electrode adjacent to the PEM **120**. These MEA components are known in the art.

Preferably, each of the openings **142** on the substrate **140** has a step-like recess **144** around its edges so as to allow an MEA segment **110** to be attached therein, as shown in Figures 4a and 4b. If the PEM **120** is made of a material that is compatible with the substrate **140**, the MEA segment **110** can be bonded to substrate **120** using a heat bonding process, for example. The heat bonding area is denoted by reference number **122**, as shown in Figure 4a. Alternatively, the MEA segment **110** is attached to the substrate **120** by an adhesive layer **124** that is resistant to methanol. It is essential that the bonding area **122** or the adhesive layer **124** provides a leak-proof seal around the edges of the MEA segments in order to prevent liquid methanol from leaking from one side to the other side of the substrate **140**.

Alternatively, two substrates **140** can be used to secure the MEA segments **110** with an appropriate bonding material **126**, as shown in Figure 4c.

In a fuel cell **200**, the fuel cell stack **100** can be sandwiched between two current collectors **150, 160** as shown in Figure 5. The current collector **150** has a plurality of channels **152** to allow the liquid methanol to circulate around the MEA segments **110** on the anode side **202**. Likewise, the current collector **160** has a plurality of channels **162** to allow air to circulate around the MEA segments **110** on the cathode side **204**. The current collectors **150** and **160** can be designed such that they also provide mechanical support to the fuel cell stack **100**. With the arrangement as shown in Figure 5, each of the MEA segments **110** acts like a separate fuel cell unit and all of the MEA segments **110** on the substrate **120** are electrically connected in parallel.

Alternatively, the MEA segments **110** can also be electrically connected in series, as shown in Figures 6a and 6b. As shown in Figure 6a, a net-like structure **171** is used to collect the electrical charge on the anode side **202** of the fuel cell **200**, and a similar structure **170** is used to collect the electrical charge on the cathode side **204** of the fuel cell **200**. The structure **171** comprises a plurality of electrically conductive segments **173**, each of which is disposed in the proximity of the anode side of an MEA segment **110**. Likewise, the structure **170** comprises a plurality of electrically conductive segments **172**, each of which is disposed in the proximity of the cathode side of an MEA segment **110**. The substrate **120** further has a plurality of electrically conductive connectors or feed-throughs **176** for electrically connecting one electrically conductive segment **173** to one electrically conductive segment **172**. The MEA segments **110** so connected are effectively a plurality of fuel cell units connected in series. Preferably, an electrically non-conductive housing **180** is used to support the fuel cell stack **100** and the net-like structure **171** on the anode side **202**, and another electrically non-conductive housing **190** is used to support the fuel cell stack **100** and net-like structure **170** on the cathode side. It is understood that the net-like structures **170, 171** are designed such that while the electrically conductive segments **173**, along with the electrically conductive segments **172**, can be used to collect electrical current efficiently, the electrically conductive segments **172, 173** also allow liquid methanol and air to circulate sufficiently around the MEA segments **110** via the flow channels **182** in the housing **180** and the flow channels **192** in the housing **190**.

In a different embodiment of the present invention, each of the activation layers **112** and **114** is extended beyond the PEM **120** so that it can be electrically connected to a feed-through **176**, as shown in Figure 6b. As mentioned above, the activation layer **112** comprises an electrode facing the PEM **120** and the activation layer **114** also comprises an

electrode facing the PEM **120**. Through the feed-through **176**, the electrode on the activation layer **112** of one MEA segment **110** is electrically connected to the electrode on the activation layer **114** of an adjacent MEA segment **110**. The MEA segments **110** so connected are also effectively a plurality of fuel cell units connected in series. Advantageously, the fuel cell **200** also has a housing **198** to provide mechanical support to the fuel cell stack **100**.

It is understood that the electrical connection among the MEA segments **110** in a fuel cell stack **100** can also be a combination of series connection and parallel connection. The combination can be tailored to suit the voltage and power requirements of a portable electronic device.

Figures 2a, 2b, 4a to 6b illustrate a fuel cell stack **100** in a fuel cell **200**. The fuel cell stack **100** comprises a plurality of MEA segments **110**, as shown in Figure 3. Each of the MEA segments **110** comprises a pair of activation layers attached to a PEM **120** on opposite sides thereof. As such, each MEA segment **110** can be considered as being the component of a single cell. When a fuel cell **200** is defective due to inefficiency of proton exchange, it is possible that only one or two of such single cells are defective. In such cases, it is possible to replace only the MEA segment **110** of the defective single cells. Because the PEM is usually the most expensive component in a fuel cell, replacing a small PEM in an MEA segment **110** is more economical than discarding the entire PEM in a prior art fuel cell as depicted in Figure 1.

Furthermore, when a fuel cell is fabricated to suit the size or the power consumption of a portable electronic device, it is possible to use a different number of MEA segments to fit the size of the fuel cell **200**. For example, it is possible to fabricate one fuel cell with 4x6 MEA segments and to fabricate another fuel cell with 5x7 MEA segments of the same size. In contrast, with the prior art fuel cells, one must have PEMs of different sizes to suit the size of different portable electronic devices.

It should be noted that each MEA segment can be made of two or more pairs of activation layers attached to a PEM **120** on opposite sides thereof. As shown in Figure 7a, each MEA segment **110a** comprises two activation layers **112** and two activation layers **114** (not shown), attached to opposite sides of a PEM **120**. As such, each MEA segment **110a** can be considered as the component of two cells. As shown in Figure 7b, each MEA segment **110b** comprises four activation layers **112** and four activation layers **114** (not shown), attached to opposite sides of a PEM **120**. Similarly, each MEA segment **110c**

comprises six activation layers **112** and six activation layers **114** (not shown), attached to opposite sides of a PEM **120**. With different MEA segments, it is possible to combine those MEA segments to form a fuel cell of a certain size. For example, when it is desirable to fabricate a fuel cell using a substrate **140** having 2x3 openings as shown in Figure 2b, it is possible to use 3 two-cell MEA segments **110a** (see Figure 7a), but it is also possible to combine one two-cell MEA segment **110a** and one four-cell MEA segment **110b** (see Figure 7b). One may also use only one six-cell MEA segment 110c to fabricate a fuel cell of the same size. However, as the number of cells on a single MEA segment increases, the area of the PEM **120** also increases. The cost effectiveness in replacing a PEM in a defective cell is reduced accordingly. Nevertheless, multiple-cell MEA segments offer a convenient way in fabricating fuel cells for portable electronic devices of various sizes.

It should be noted that the individual "cell" in a single or multiple-cell MEA segment can be square, or rectangular with a certain aspect ratio to suit a variety of fuel cell sizes. For example, the aspect ratio for the individual cell can be 4:3 or 5:4.

In addition, the size of MEA segments for a fuel-cell stack need not be the same. As seen in Fig. 8, two smaller MEA segments **210** are combined with 4 MEA segments **110**.

In sum, the membrane electrode assembly in a fuel cell can be made of a plurality of segments, each having a separate proton exchange membrane. As such, it is possible to replace a defective segment, instead of discarding the entire membrane electrode assembly, if the fuel cell becomes defective. With membrane electrode assembly segments, fuel cells of various sizes can be made without using proton exchange membranes of different sizes. In a fuel cell having a plurality of membrane electrode assembly segments, it is possible to electrically connect the segments in series, in parallel or in a combination thereof.

Although the invention has been described with respect to a preferred embodiment thereof, it will be understood by those skilled in the art that the foregoing and various other changes, omissions and deviations in the form and detail thereof may be made without departing from the scope of this invention.